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Orthopaedics
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Surgery & Research

ORIGINAL ARTICLE

Anterior versus posterior approach in 3D correction of adolescent idiopathic thoracic scoliosis: A meta-analysis

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Accepted: 1st June 2012

KEYWORDS

Systematic review;
Meta-analysis;
Idiopathic scoliosis;
Surgery;
Approach

Summary

Purpose: Systematic review was conducted to compare effectiveness and safety of anterior and posterior surgical approach in 3D correction of adolescent idiopathic thoracic scoliosis.

Methods: Data sources were MEDLINE and SCOPUS databases. We included studies on the use of either anterior or posterior instrumentation, or their combination, in surgical correction of adolescent idiopathic thoracic scoliosis, with at least 10 enrolled patients, aged less than 20 years at the time of surgery, and a follow-up of at least 24 months. A study was eligible if it reported the number of patients, mean estimate and dispersion of three key outcome measures (frontal and sagittal Cobb angle, apical vertebra rotation according to Perdriolle) at three measurement points (preoperatively, postoperatively, at follow-up). The quality of studies was assessed using the scale by Pilkington.

Results: Although 24 articles met the inclusion criteria, no randomized controlled trials (RCT) was identified. None of the articles was of high quality. Both instrumentations provided a similar degree of reduction of frontal Cobb angle. Long-term effects of surgical correction on the sagittal Cobb angle seemed to be more stable in patients treated by posterior approach, while the anterior approach was more effective in the reduction of apical vertebral rotation. The surgery parameters were more favorable for anterior approach, particularly for the number of fused vertebrae.

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Conclusions: Although the available evidence favors neither of the two approaches, our study revealed several important issues: the reports are heterogeneous and provide incomplete relevant information. High quality studies, particularly RCT, are called for.

Level of evidence: Level II.

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Introduction

Adolescent idiopathic scoliosis is traditionally treated by posterior instrumentation and fusion, resulting in excellent functional results and providing a solution for any combination of deformities [1–4].

The shortcomings of posterior approach, such as limited ability to correct with the rotational component of the thoracic spine deformity [5], led to the development of anterior approach [6,7], which has been significantly refined and improved over time [8–10]. Anterior approach has been associated with better thoracic volume correction than posterior approach [11]. Occasionally, a significant number of distal vertebral segments could be also saved by the use of anterior instrumentation, with an excellent lumbar curve correction [10,12]. However, the anterior approach offers no possibility to correct the partial or complete high left structural thoracic curve [13].

Since the benefits of anterior vs. posterior approach in adolescents with idiopathic thoracic scoliosis are still controversial and no superiority of one over the other has been proven [13], we performed a systematic literature review and meta-analysis to elucidate this issue.

Materials and methods

Inclusion and exclusion criteria

We included studies on the use either anterior or posterior instrumentation, or their combination, in surgical correction of adolescent idiopathic thoracic scoliosis, published from 1st January, 1990 to 1st October, 2010, in English or German, with at least 10 enrolled patients aged less than 20 years at the time of surgery, and a follow-up of at least 24 months.

MEDLINE and SCOPUS databases were searched. MEDLINE was searched using the Mesh terms Scoliosis+surgery, and then text words “idiopathic” and “posterior OR anterior”. The results were limited to the age group “adolescent” and publication date 1990–2010. SCOPUS database was searched for the same period using the keywords “scoliosis”, “surgery”, “idiopathic”, “posterior”, “anterior”, “adolescence” (“adolescent”, “adolescents”) in the title, abstract, and keyword fields and then by combining the queries.

By MEDLINE search, we identified 550 articles, while the query of SCOPUS database resulted in 686 articles, 519 of which overlapped with those identified in MEDLINE. Thus, a total of 717 articles were included in the subsequent step. Two investigators independently reviewed the titles and abstracts to identify eligible articles for further full text assessment. The same two reviewers evaluated full texts of

287 articles and selected 74 articles that met the inclusion criteria.

We excluded 46 studies due to the partial or complete lack of data on three measurement points. Finally, we performed a preliminary data analysis and identified four studies (six patient groups) with a follow-up of over 150 months. These studies were considered outliers and were omitted from the further analysis, which left 24 studies for the meta-analysis (Fig. 1) [10,12,14–35].

Outcome measures and data extraction

The articles included in our study were used to form a database for data retrieval. Primary outcome measures were frontal thoracic Cobb angle, sagittal thoracic Cobb angle [36], and apical vertebral rotation according to Perdriolle [37]. We also recorded the type of reported complications, duration of the surgery, bleeding, fusion, duration of hospital stay and follow-up; and the type of journal, type of study, type of intervention, and number of patients.

For the purpose of the analysis, we defined a patient group as the main observational unit. A patient group was eligible for the analysis of a particular primary outcome measure if the number of patients, mean estimate, and a measure of dispersion at all three measurement points (preoperatively, postoperatively, at follow-up) were reported.

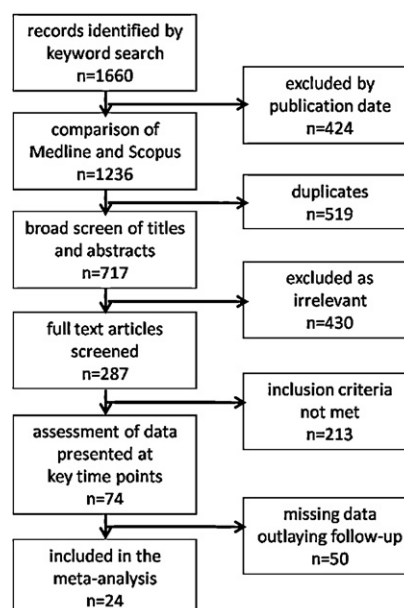


Figure 1 Flow chart of the selection process for meta-analysis of manuscripts reporting on the anterior and posterior approach in patients with adolescent thoracic idiopathic scoliosis.

Table 1 Preoperative condition of the patients with idiopathic adolescent thoracic scoliosis recruited in the systematic review on anterior vs. posterior surgical approach. The data are presented as mean with standard deviation, while the difference is given as mean with 95% confidence interval.

Surgical approach	Angle [°]		
	Frontal thoracic Cobb	Sagittal thoracic Cobb	Apical vertebra rotation according to Pedriolle
Anterior	57.5 ± 3.8	24.6 ± 5.8	26.8 ± 7.4
Posterior	54.1 ± 4.5	23.8 ± 6.7	20.8 ± 8.3
Difference	−3.4 (−12.2 to 5.4)	−0.7 (−13.8 to 12.3)	−6.0 (−22.2 to 10.3)

Patient groups for which the aforementioned data were not reported were excluded from the subsequent analysis of the respective outcome measure.

Quality assessment

To assess the quality of the included articles, we used the scale described by Pilkington et al. [38].

Data analysis

Key measures of success of a particular surgical approach were first summarized under a random-effects model, due to heterogeneity of instrumentations and other conditions in analyzed studies. An exception was made regarding the key measure of anterior approach for apical vertebral rotation according to Perdrille [37], because only a single study was eligible. Pooled results of anterior and posterior approaches were further analyzed under a fixed-effect model [39]. Analysis and graphics were produced using “metafor” library (version 1.5–0) [40] for R statistical environment (version 2.13.0) [41]. The threshold of statistical significance was set at 0.05 and 95% confidence intervals (95% CI) were used where appropriate.

Results

The literature search resulted in 24 articles that met all the inclusion criteria (Fig. 1). Only one study was a historical cohort. The remaining studies were of concurrent cohort design. Twenty articles (83%) were published in *Spine* (18 articles) and *European Spine Journal* (two articles). Seventeen (71%) articles were of average and seven (29%) of low quality according scale by Pilkington et al. [38].

Thirteen studies (54%) analyzed patients operated exclusively by posterior approach. Anterior approach as the only procedure was described in five (21%) articles, and two articles reported on the comparison of anterior and posterior approach. The remaining four articles (17%) focused on comparisons of various types of posterior approach.

Surgical results

The studies in the meta-analysis included a total of 1555 patients: 1233 (79%) were operated using posterior and 322 (21%) using anterior approach. They were divided into 29 groups, 22 (76%) of which included patients

operated by posterior approach. Nine different posterior instrumentations were used, the most frequent one being multi-segmented hook-screw instrumentation (six groups), followed by Cotrel-Dubousset (CD) instrumentation (five groups). Anterior approach was less variable with respect to the instrumentation. For example, Zielke's instrumentation (or its modifications) was used in four patient groups, whereas the remaining four instrumentations were used to operate on one group each.

The comparison of primary outcome measures before the surgery between the patients operated by posterior and anterior approach showed no significant differences in Cobb's angles or apical vertebra rotation (Table 1). The median follow-up was 30 months (range 24–102 months) and, when tested, the follow-up time was not significantly associated with the outcome variables (not shown).

The preoperative to postoperative difference in frontal Cobb's angle reported by the studies using anterior approach varied between 30.0° [29], and 51.9° [10], being 37.8° on the average (95% CI: 33.2° to 42.4°) (Fig. 2). The effect of posterior approach on the reduction of frontal Cobb's angle was slightly smaller (mean difference 33.0°; 95% CI: 30.4° to 35.7°; range 24.0° to 43.0°). The resulting difference between the two surgical approaches was thus modest (−4.8°; 95% CI: −10.1° to 0.6°) and not statistically significant ($Q_{M1} = 3.07$, $P = 0.080$). We next compared the difference between preoperative and follow-up findings (Fig. 3). The range of reduction in the frontal thoracic Cobb angle in the studies reporting anterior approach was 20.9°, with a notable contribution of the study by Franić et al., i.e. reduction of 47.9° [10]. Similar findings were obtained for the posterior approach group: the mean preoperative to follow-up difference was 28.8° (95% CI: 25.6° to 32.0°; range 21° to 38.4°) and, when compared to the anterior approach group, no significant difference was found ($Q_{M1} = 2.59$, $P = 0.108$). When we compared the effect of the approach on the loss of correction (i.e. follow-up to postoperative difference), there were almost no differences between the techniques (difference 0.67°; 95% CI: −1.5° to 2.9°; $Q_{M1} = 0.36$, $P = 0.548$) (Fig. 4).

Anterior approach led to the average postoperative increase in the sagittal Cobb angle of −3.3° (95% CI: −6.1° to −0.6°). The efficacy of posterior approach was similar to that (average increase: −0.23°; 95% CI: −3.1° to 2.6°) and the difference between the two approaches (3.1°; 95% CI: −0.8° to 7.0°) was not statistically significant ($Q_{M1} = 2.37$, $P = 0.124$). The reported range of postoperative increase in the sagittal Cobb angle was wider with posterior (23.4°)

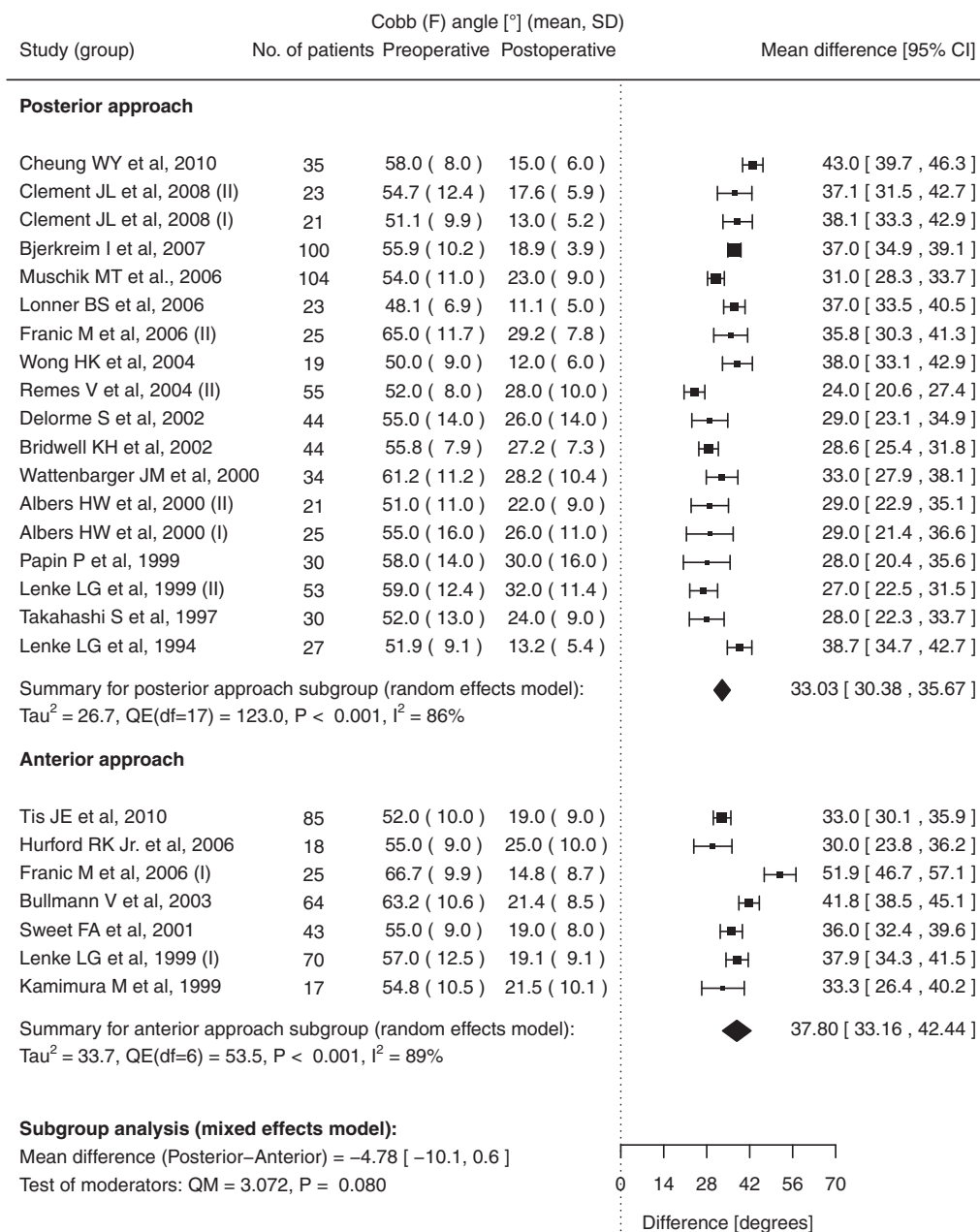


Figure 2 Meta-analysis of the effect of posterior and anterior surgical approach on the preoperative and immediate postoperative frontal thoracic Cobb angle in patients with adolescent idiopathic thoracic scoliosis. The angles and their differences were summarized as mean and standard deviation (SD) or 95% confidence interval (CI).

than anterior approach (8.4°). When we compared the preoperative values of sagittal Cobb angle to the ones at follow-up, the difference in performance of anterior vs. posterior approach was 5.6° (95% CI: 1.5° to 9.8°; QM₁ = 7.02, P = 0.008). Again, the variability of the posterior approach was considerable, with a mean increase in sagittal Cobb angle ranging from -17.7° [15] to 6.0° [31]. The direction of the approach did not influence the difference between the postoperative findings and follow-up (difference: 2.3°; 95% CI: -1.2° to 5.8°; QM₁ = 1.61, P = 0.204) (Fig. 4).

Only a single study on anterior instrumentation [24] and five studies on the posterior instrumentation reported on apical vertebral rotation [16,18,19,22,27]. The results

of postoperative rotation reduction, reported by Bullman et al. [24] differed significantly from other posterior studies (difference: -8.6°; 95% CI -13.5° to -3.7°; QM₁ = 11.88, P < 0.001). Moreover, when the preoperative findings were compared to the follow-up findings, the result of the study describing anterior approach showed improved reduction in the apical vertebral rotation (12.9° [95% CI 10.5° to 15.3°] vs. 4.2° [95% CI 2.3° to 6.1°] in the posterior studies; QM₁ = 31.69, P < 0.001). On the other hand, the postoperative loss of correction was not associated with the technique: the surgical approach had a comparable average postoperative to follow-up difference (-0.3°; 95% CI -4.6° to 3.9°; QM₁ = 0.02, P = 0.880) (Fig. 4).

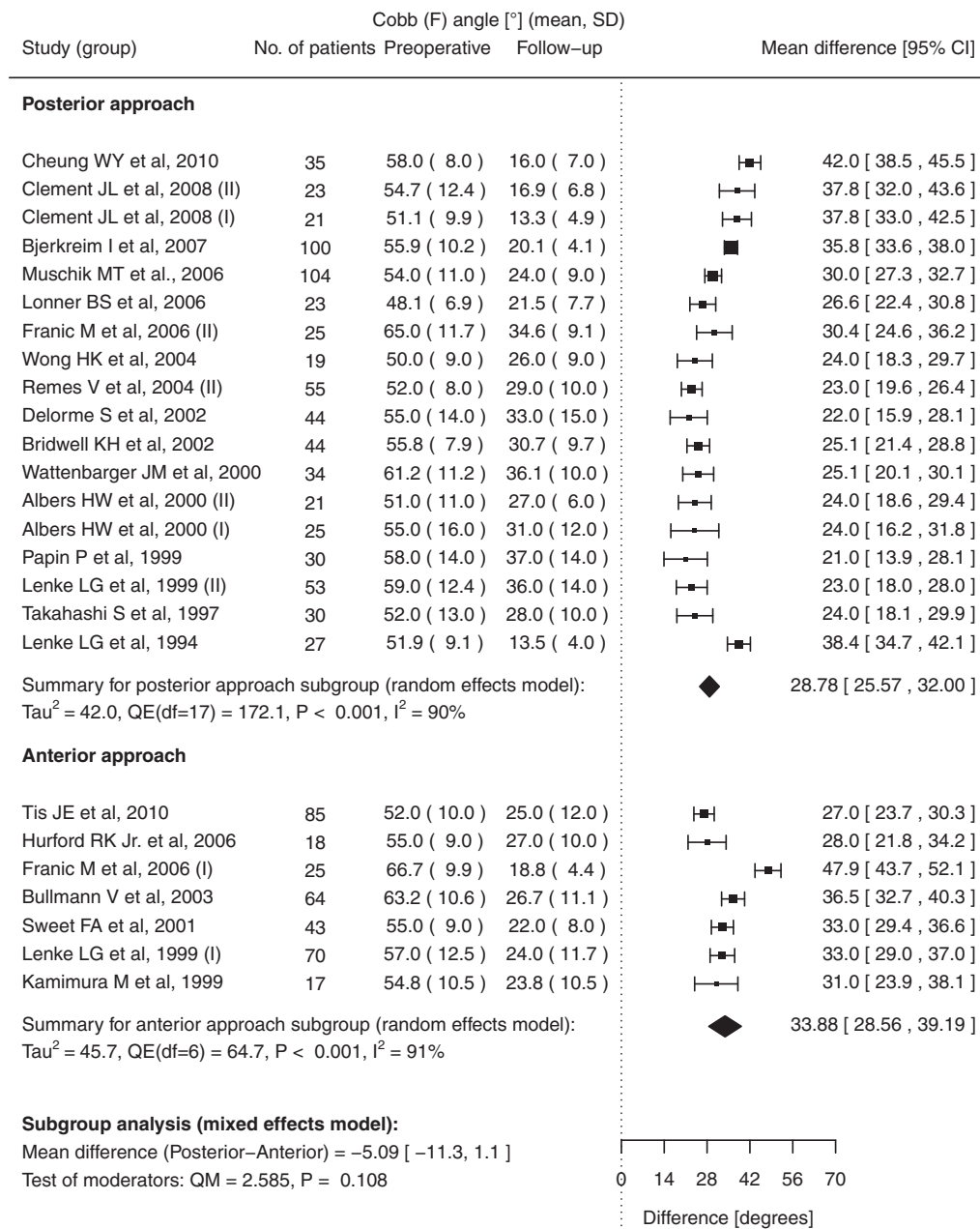


Figure 3 Meta-analysis of the effect of posterior and anterior surgical approach on the preoperative and follow-up (minimum 24 months) frontal thoracic Cobb angle in patients with adolescent idiopathic thoracic scoliosis. The angles and their differences were summarized as mean and standard deviation (SD) or 95% confidence interval (CI).

Other results

The posterior procedures lasted on average 65 minutes longer than the anterior ones (219 ± 36 min vs. 154 ± 32 min respectively) ($QM_1 = 3.21$, $P = 0.073$) and were associated with more blood loss, which was almost twofold higher on average than blood loss observed with the anterior approach (921 ± 321 mL vs. 442 ± 220 mL, respectively, $QM_1 = 2.23$, $P = 0.135$). Subsequently, the hospital stay of patients who underwent the posterior procedure was longer: posterior 10.0 ± 3.0 days vs. anterior 6.4 ± 3.1 days ($QM_1 = 1.32$, $P = 0.250$). The anterior approach resulted in fewer fused

vertebrae than the posterior approach (anterior 7 ± 0.6 vs. posterior 10 ± 1.1 ; $QM_1 = 7.98$, $P = 0.005$).

Of 24 manuscripts included in the meta-analysis, only 14 (58%; 16 patient groups) reported related complications (Table 2).

Discussion

This is the first meta-analysis comparing the anterior and the posterior surgical approach in the correction of adolescent idiopathic thoracic scoliosis. We analyzed the two surgical

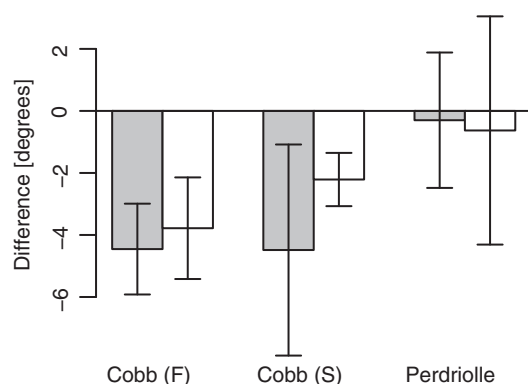


Figure 4 Effect of posterior (closed columns) and anterior (open columns) surgical approach on the difference between follow-up and postoperative values of frontal thoracic Cobb angle (Cobb F), sagittal thoracic Cobb angle (Cobb S), and apical vertebra rotation according to Pedriolle [15] in patients undergoing correction of adolescent idiopathic thoracic scoliosis. Summarized results of the meta-analyses are given as mean and 95% confidence interval.

approaches by evaluating the outcomes in all three body-planes. Moreover, analysis of follow-up data enabled us to assess the long-term effects of the surgery.

The average correction of the frontal Cobb angle immediately after the surgery was 66% with the anterior and 61% with the posterior approach, while the average correction at two-year follow-up was 59% and 53%, respectively. Similarly, the comparison of two concurrent cohorts by Betz et al. [13] did not show any differences between the two approaches at two-year follow-up: average correction was 58% in the anterior group and 59% in the posterior group. A previous systematic review of the effect of thoracoscopic instrumentation in adolescents with idiopathic thoracic scoliosis also found a similar correction of the frontal Cobb angle of 65% [42]. However, patient age in that study ranged from 10 to 33

years at the time of surgery (average, 14.3 years) and follow-up times were not only quite variable (range 0–44 months), but also much shorter than ours, i.e. average 17.6 months vs. minimally 24 months in the present meta-analysis.

The analysis of the results in the sagittal plane revealed that the anterior approach was associated with a mild kyphotic effect (i.e. average preoperative to follow-up difference of -7.9° and -2.3° with anterior and posterior approach, respectively). Our results thus confirmed the findings of Rhee et al. [43], demonstrating kyphogenic effect of anterior thoracic instrumentation. As most patients with scoliosis are hypokyphotic [13], that effect could be considered as a relevant advantage of the anterior over the posterior approach.

Katwicky et al. [44] concluded in their comparative study that anterior instrumentation provided better correction of both the vertebral axial rotation and of the rib hump. CD instrumentation was more powerful in translation and more specifically addressed the sagittal plane: the postoperative thoracic kyphosis angle increased in the hypokyphotic curves and slightly decreased in the normokyphotic curves.

With respect to the apical vertebra rotation [37], the anterior correction reached 49% (i.e. a relative difference between the preoperative and postoperative angle), which was significantly different from the average correction of 22% achieved by the posterior approach. Since only a single manuscript on anterior instrumentation and five manuscripts on posterior instrumentation reported the values of Pedriolle's angle, our results should be interpreted with due caution.

The study by Illés et al. [45] aimed at the 3D visualization of spine deformities with the EOS 2D/3D system, with interpretation of the horizontal plane view of 3D deformities and introduction of the concept of vertebra vectors, which permit a truly 3D classification of scoliosis what is the future for new classifications and postoperative evaluation.

Our data showed a pronounced heterogeneity among the analyzed studies. High values of I^2 indices, reaching up to 91%, point to a high diversity between the primary reports included in the meta-analysis and call for caution during the interpretation of the results. The causes of that heterogeneity are complex, but the one that should be emphasized is the number of different instrumentations used for both surgical approaches.

Another example of inconsistent reporting of results is surgical complications: almost half of the analyzed manuscripts did not mention any. Although the total complication rate did not differ significantly between the two surgical approaches, the re-operation rates in the patients operated by posterior approach were approximately three times higher than those in patients operated by the anterior approach. In addition, the use of anterior instrumentation can easily eliminate problems inherent to the posterior instrumentation. If we considered the options for surgical treatment of scoliosis in even broader context, the thoracoscopic method was characterized by increased cosmetics, but burdened by high complication rate and long learning curve [46].

The lack of uniform reporting standards strongly influenced the selection of manuscripts and was the main reason for exclusion. Of 74 manuscripts that met the inclusion criteria, 50 (68%) had to be excluded due to either incomplete

Table 2 Complications reported in manuscripts included in the meta-analysis of anterior (252 patients) vs. posterior (464 patients) surgical approach in patients with idiopathic adolescent thoracic scoliosis.

Complication	Anterior approach patients <i>n</i> (%)	Posterior approach patients <i>n</i> (%)
Re-operation	3 (1.2)	24 (5.1)
Infection	1 (0.4)	16 (3.4)
Neurological	0 (0)	2 (0.4)
Implant breakage	16 (6.3)	7 (1.5)
Implant dislocation	4 (1.6)	11 (2.4)
Pseudoarthrosis	5 (1.9)	4 (0.8)
Loss of correction	2 (0.8)	5 (1.1)
Painful instrumentation	0 (0)	7 (1.5)
Other ^a	1 (0.4)	2 (0.4)
Total	32 (13)	78 (17)

^a Includes cast syndrome, urinary infection, atelectasis, effusion.

reporting of key outcome measures or too short follow-up. Future studies should include the main outcome measures before and immediately after the surgery, use the follow-up of at least 24 months, and report on the number of patients, outcome measures summarized by a point-estimate, and a measure of variability. That should eliminate at least some sources of bias and allow for more comprehensive data analysis and more reliable conclusions.

We particularly emphasize the lower number of fused vertebrae following the anterior surgical approach (i.e. on average three vertebrae fewer than with the posterior approach). In this sense, the present meta-analysis is in the line with the view of Halm et al. [47] that the anterior instrumentation allows for the selective fusion of the thoracic spine. They also reported less blood loss, better derotation, better effect on the sagittal plane control especially for hypokyphotic thoracic scoliosis as advantages of modern anterior instrumentation systems [47]. Since other reports also pointed to the lower back pain as a consequence of lumbar fusion [48], the difference in the number of fused vertebrae between the two surgical approaches, as shown in our study, should be considered clinically relevant and acknowledged during the planning stage of the operative procedure. In addition, future studies should try to assess patient's quality of life after scoliosis surgery, which was not the case with the studies included in our meta-analysis [49].

The evaluation of the quality of articles by using the instrument developed by Pilkington et al. [38] revealed that not a single manuscript could be considered of high quality and a third were of low quality. These facts imply that our initial data were of moderate scientific and methodological soundness, which has to be taken into account when interpreting our findings. We suggest a uniform design for prospective studies and call for more high quality studies.

In conclusion, our meta-analysis showed that both instrumentations provide a similar degree of frontal Cobb angle reduction. The long-term effects of surgical correction on sagittal Cobb angle seemed to be more stable in patients treated by the posterior approach, while the anterior approach was more effective in the reduction of apical vertebra rotation. Surgery parameters were more favorable for the anterior approach, particularly with respect to the number of fused vertebrae. Although the available evidence does not allow for a clear-cut decision on the choice of surgical approach, our study points to several important issues in orthopedic practice: study reports should be more homogenous and include all relevant information. High quality studies will be essential for making the final recommendation on surgical approach for the correction of idiopathic adolescent thoracic scoliosis.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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